Introduction

A **prokaryote** (Gk. *Pro* = before, *Karyons* = nucleus) is a unicellular organism having simple structure that lacks a membrane-bound nucleus and other membrane-bound organelles like mitochondria, Golgi complex etc. Prokaryotes have great economic and environmental importance. They also greatly affect on human health and largely used in research and biotechnology.

6.1 Taxonomy of Prokaryotes

The A. V. Leeuwenhoek (Dutch scientist) first discovered bacteria in 1674 and called them **animalcules**. Ehrenberg introduced the name **bacterium** in 1828 (Gk: bacterion means small staff or rod). The taxonomic position of bacteria and other prokaryotes have witnessed continuous changes since their discovery.

6.1.1 Taxonomic position of Prokaryotes as kingdom(Monera)

According to two kingdom system of classification all microorganisms were included in kingdom **Plantae.** In 1861 **John Hog** proposed a separate kingdom **Protista** for all microorganisms including **bacteria.** In 1866 **Ernst Haeckel** made a separate group the **Monera** for Prokaryotes within same kingdom Protista. In 1938 **Herbert Copeland** separated group Monera from Protista and formed the **kingdom Monera** in which he had placed only prokaryotic organisms. **Robert H. Whittaker** an American biologist in 1969 proposed five kingdom system of classification for living things. **Lynn Margulis** and **Karlene Shwartz** in 1988 modified five kingdom classification. They distinguished between kingdoms according to cellular organization and mode of nutrition. They had placed all prokaryotes in kingdom monera, whereas eukaryotes were classified into four kingdoms *viz.* Protista, Plantae, Fungi and Animalia.

6.1.2 Taxonomic position of prokaryotes as "Domain Bacteria" and "Domain Archaea"

Earlier the term bacteria was used for all microscopic unicellular prokaryotes but later molecular systematics studies exhibit that prokaryotic life consists of two separate **domains**. Thus, both these domains have superceded the kingdom as a broadest taxonomic group. Bacteria and Archaea evolved independently from an ancient common ancestor. These two domains, along with Eukarya, are the basis of the three domain system, which is currently the most widely used classification system in bacteriology.

6.1.3 Phylogenic position of prokaryotes

Phylogeny is the evolutionary relationship among various groups of organisms (e.g., Species or populations). The study of phylogenic evolutionary history of a species or group of related species is called **systematics**. The bacterial phylogeny was reconstructed in 1977. The new phylogenetic taxonomy is based on the discovery of genes encoding ribosomal RNA because there is little or no change in ribosomal RNA generation after generation. **Thus ribosomal RNA are commonly recommended as**

molecular clock for reconstructing phylogenies. Now prokaryotes are divided into two evolutionary domains as part of the three domain system, **Archaea Eubacteria** and **Eukaryotes.** The genes sequence studies indicate that bacteria diverged first from the archaeal/ eukaryotic lineage.

Most scientists hold view that bacteria and archaea probably evolved from **hyperthermophile** that lived about 2.5 to 3.2 billion years ago.

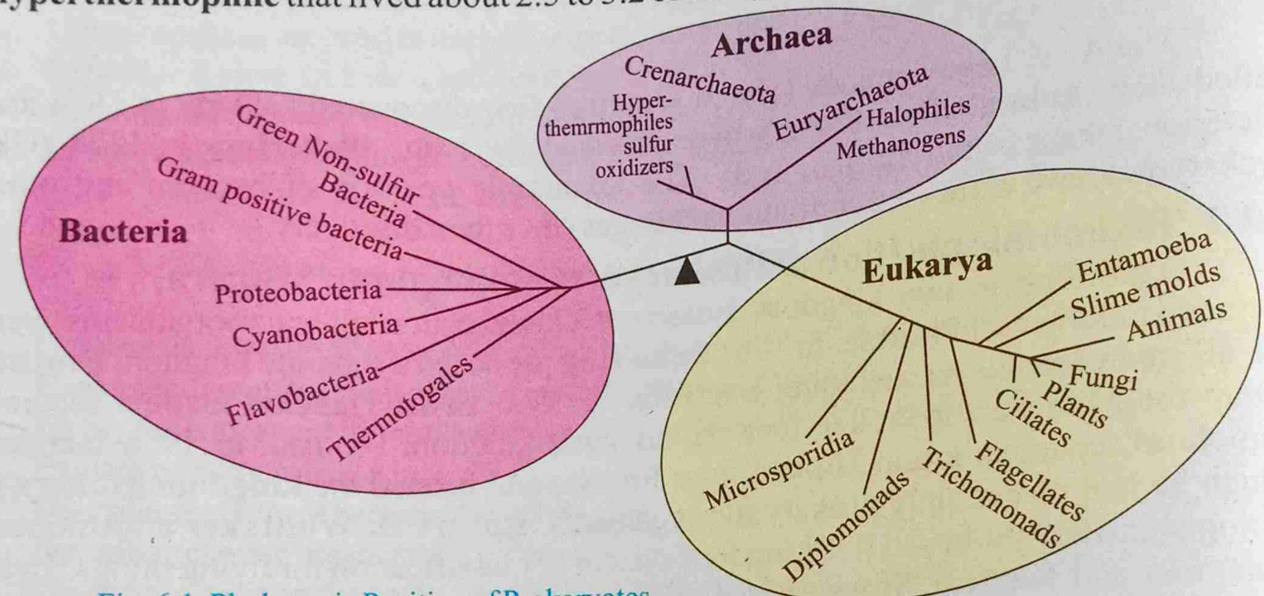

Fig. 6.1 Phylogenic Position of Prokaryotes

6.2 Archaea

The microorganisms belong to domain archaea are unicellular prokaryotes, previously known as **archaeobacteria**. Archaea exhibit similarities both with bacteria as well as eukaryotes.

They also differ from bacteria and possess unifying features thus placed in separate domain. The **unifying archaeal features** are:

1. Their **plasma membrane** contains different kinds of lipids than bacteria which allows them to function at high temperature.
2. The **cell wall** in bacteria is made up of carbohydrate-protein complex called **peptidoglycan** but the cell wall of archaea lacks this complex. Their cell wall is largely composed of polysaccharides or pure protein.
3. The **rRNA** of archaea is unique, i.e., different from that of bacteria.
4. **Lipid** of bacteria contain glycerol with fatty acids while lipid of archaea contain glycerol linked to branched chain of hydrocarbons.
5. A unique ability of **methanogenic** archaea is formation of methane.
6. Archaea are mostly **autotrophs**.

6.2.1 Habitat of Archaea

Most live in extreme environments. There are three types of archaea:

(i) Methanogenic archaea (ii) Halophiles

(iii) Thermoacidophilies.

The **methane** (Biogas) producing archaea are known as **methanogen,** which inhabit anaerobic environments like marshes, swamps, digestive tract of animals and human. These archaea produce biogas (methane) from hydrogen gas and CO_2 coupled to the formation of ATP (example of methanogen is *Methanobacterium formicom*).

The **halophiles**, inhabit salty environment where other organisms can not live such as salty meat, example of halophiles is *Halobacterium halobium*.

The **thermoacidophiles** inhabit extreme hot and acidic environments. Their example is *Pyrolobus fumarii,* recorded in hot springs, geysers, volcanoes etc.

6.3 Bacteria Ecology and Diversity

Bacteria have a wide range of habitat. They exhibit diversity in their size, shape and mode of nutrition.

6.3.1 Occurrence

Bacteria are found everywhere in this planet where life exists such as body of living and dead organisms, water, soil, milk, skin, humid forests etc.

6.3.2 Major Groups of Bacteria

Dr. Hans Christian Gram (1884) has divided bacteria into two major groups by using staining technique, i.e. **Gram positive and Gram negative.** His grouping depends upon chemical makeup, permeability, metabolism, presence of endospores, physiological characteristics, growth and nutrition in bacteria.

Table 6.1 Comparison between Archaea and Bacteria

Basis of comparison	Archaea	Bacteria
Habitat	Unusual environment like hot springs, ocean depth, salt brine.	Everywhere like soil, water, living and non living organisms.
Cell wall	Psuedopeptidoglycan, largely composed of polysaccharide or pure protein.	Peptidoglycan with muramic acid or lipopolysaccharide.
Membrane	Branched carbon chain.	Unbranched carbon chain.
Types	Methanogen, Halophiles, Thermoacidophiles	Gram positive and Gram nagetive.
Other features	No thymine in tRNA. Introns are present. Non-pathogens RNA polymerase is complex similar to eukaryotic, mostly autotrophic but no photosynthesis.	Thymine in the tRNA. Introns are absent. Some are pathogens. RNA polymerase simple and small, photosynthesis present but mostly heterotrophic.
Examples	*Sulfolobus acidocaldarius, Pyrococcus furiosus.*	*Streptococcus pneumonia, E.coli.*

6.4 Structure, Shape and Size of Bacteria

A typical bacterium consists of cell wall, cell membrane, nuclear region, cytoplasm and also other structures outside cell wall.

> **Tit bits**
> *Peptidoglycan is also called murein. It has long chains of sugars with short chains of amino acids (normally 4-5 amino acids).*

6.4.1 Structure and Chemical Composition of Bacterial Cell Wall

All bacteria possess cell wall except Mycoplasma. The cell wall protects the cell and also gives it a definite shape. It is made up of **peptidoglycan** (sugar-protein complex found in Prokaryotes) and is rigid.

6.4.2 The cell wall of Gram positive and Gram negative bacteria

Based on the variations in the chemical components of cell wall, Danish physician, **Hans Christian Gram**, developed a staining technique in 1884 and divided bacteria into two groups i.e., Gram positive and Gram negative bacteria.

Gram Positive: These bacteria are stained blue purple with crystal violet dye. They have thick wall of peptidoglycan. They retain dye when the cells are washed with an organic solvent like alcohol.

Gram negative: These bacteria have thinner layer of peptidoglycan. They lose the dye easily when rinsed with alcohol and stain pink. The thin peptidoglycan layer is externally covered with a layer of lipopolysaccharides, lipoproteins and phospholipid. Thus they are more resistant than gram-positive against antibiotics (lipopolysaccharide impedes the entry of antibiotics).

> **Tit bits**
> *In many bacteria cell membrane invaginates into cytoplasm to form folds called mesosome which helps in cell division and replication of DNA.*

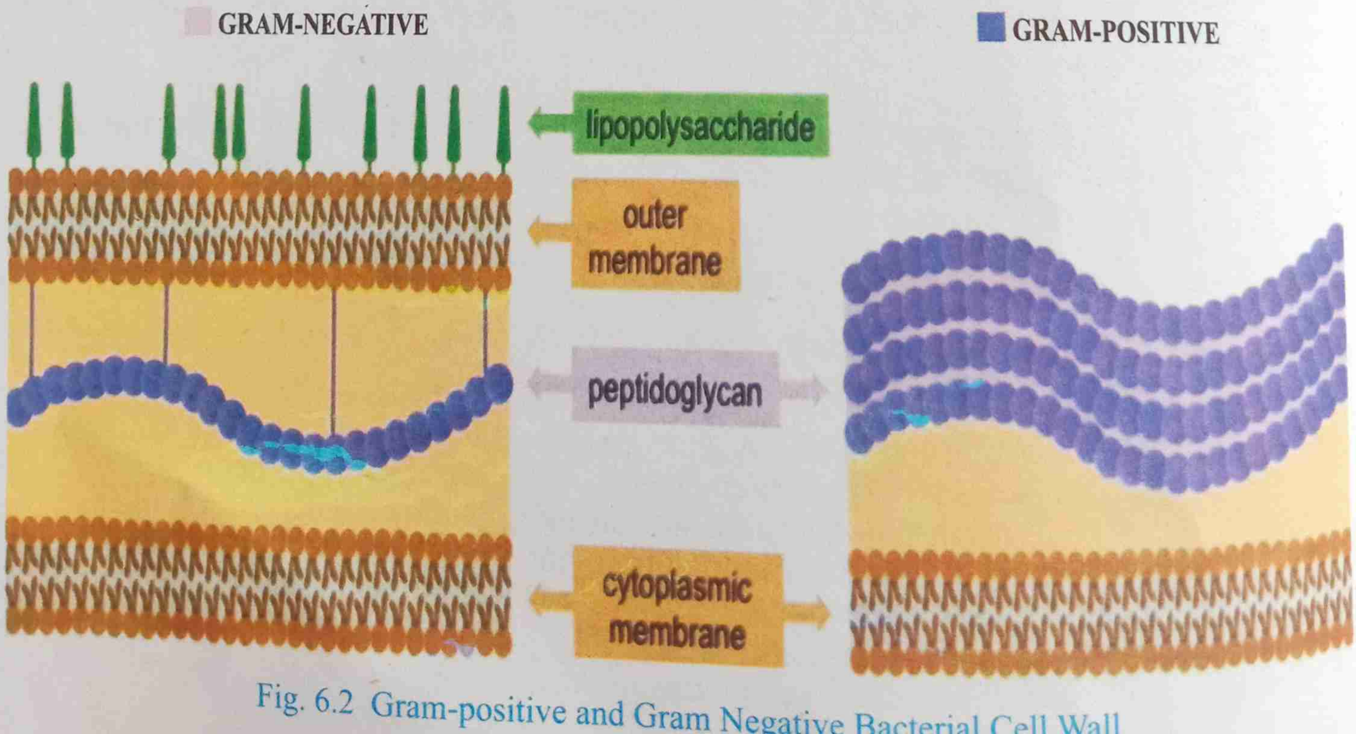

Fig. 6.2 Gram-positive and Gram Negative Bacterial Cell Wall

Table. 6.2. Differences between Gram-positive and Gram negative cell wall

Character	Gram Positive	Gram Neagative
Thickness	20 to 80 nm	8 to 10 nm
No. of Layers	One	Two
Porins proteins	Absent in all	Present in all
Peptidoglycan	More	Less
Lipid	Less	More
Outer membrane	Absent in all	Present in all
Chemical composition	Peptidoglycan, Teichoic acid, Lipoteichoic acids	Lipopolysaccharide, Lipoproteins and Peptidoglycan

Slimy Capsule:

Some bacteria contain additional protective outer envelope, secreted by the cell known as slimy capsule. It is made of polysaccharide which helps in defence and adhering to host tissues. The encapsulated bacteria cause disease while the same bacteria without capsule do not cause disease, e.g., *Diplococus pneumoniae* causes pneumonia.

6.4.3 Shape and Size of bacteria

There are three main shapes of bacteria; Spherical, Straight and Spiral shape.

Spherical or Cocci (Singular Coccus): Cocci are spherical in shape. They are non-motile because they lack flagella, may be single or colonial. The colonial may be diplococci (group of two cells) tetrad (group of four cells), octet (packet of eight cells), Streptococci (long chain of cells), Staphylococci (bunch of cells like grapes). Examples of Cocci are *Streptococcus pneumoniae, Neisseria meningitidis* etc.

Straight Shape or Bacilli (Singular Bacillus): Bacilli are straight or rod shaped bacteria. They posses flagella and are motile. Most of them occur either singly or colonial. They are found in pairs (diplobacillus), very short and oval shaped (coccobacilli), curved and coma shaped (Vibrio), stack (Pallisade). Examples of bacilli are *Bacillus subtilis, Escherichia coli* etc.

Spiral Shaped or Spirochetes: These are corkscrew shaped bacteria, flexible, motile and flagellated. They usually occur singly and seldom form colonies e.g., *Helicobacter pylori* and *Treponema pallidum.*

Most bacteria range in size about 0.1 to 600 micrometer over a single dimension.

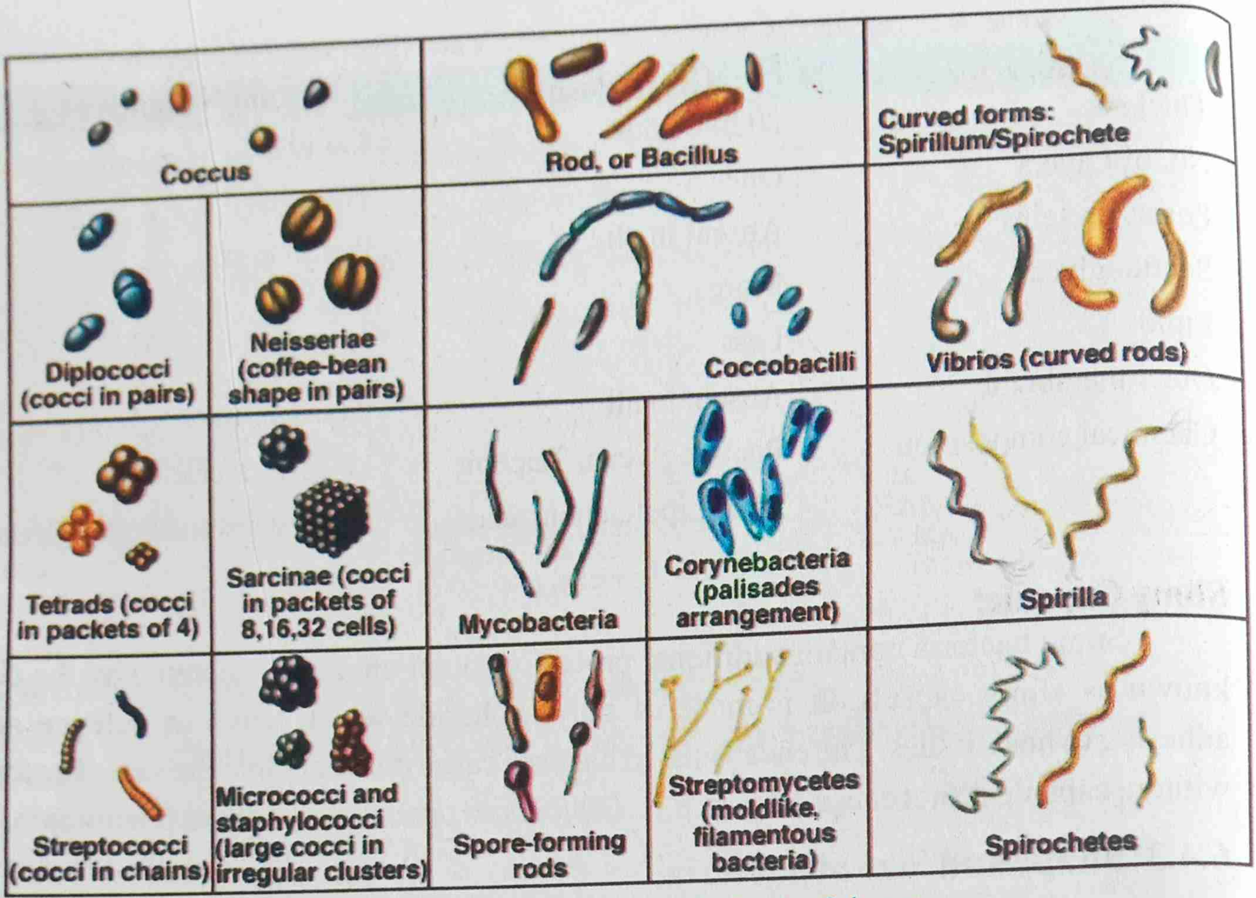

Fig. 6.3 Types of bacteria on the basis of shapes

6.4.4 Endospores

Some Gram-positive bacteria produce highly resistant structure known as endospore which during unfavorable conditions serves for the survival of the bacteria. It develops within vegetative cell, so named endospore. The original cell forms a copy of its chromosome and covers it with hard wall, water is removed and metabolism stops.

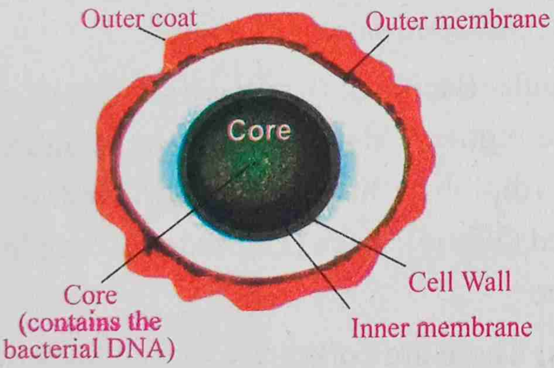

Fig. 6.4 Endospore in Bacteria

Do you know?

Pili are small hollow appendages mostly present all around the body. Their role is attachment of bacteria to host tissue, mating (conjugation) and chemotaxis.

Endospores remain dormant but viable for centuries. The parent body disintegrates. At the return of favorable conditions endospores are reactivated to normal form and restart division cycle.

6.4.5 Locomotion in Bacteria

Most bacteria possess flagella as locomotary appendages, which help in gliding, twitching motility or change of buoyancy. The spirochetes have helical body which help them to twist about as they move. During twitching motility pili help in anchoring. Flagella are commonly found in bacilli and spirilla while most cocci are without flagella known as atrichous. There are two types of arrangement of flagella, i.e., polar and peritrichous.

Polar flagella are situated at one end or both ends of bacteria and divided into following types.

Monotrichous: single flagellum at one end, e.g., *vibrio*.

Lophotrichous: a cluster of flagella at one, end e.g., *spirillum*.

Amphitrichous: flagella at both poles.

Amphilophotrichous: tuft of flagella at both ends.

Peritrichous: flagella are arranged all around the body e.g ., *Salmonella typhi*.

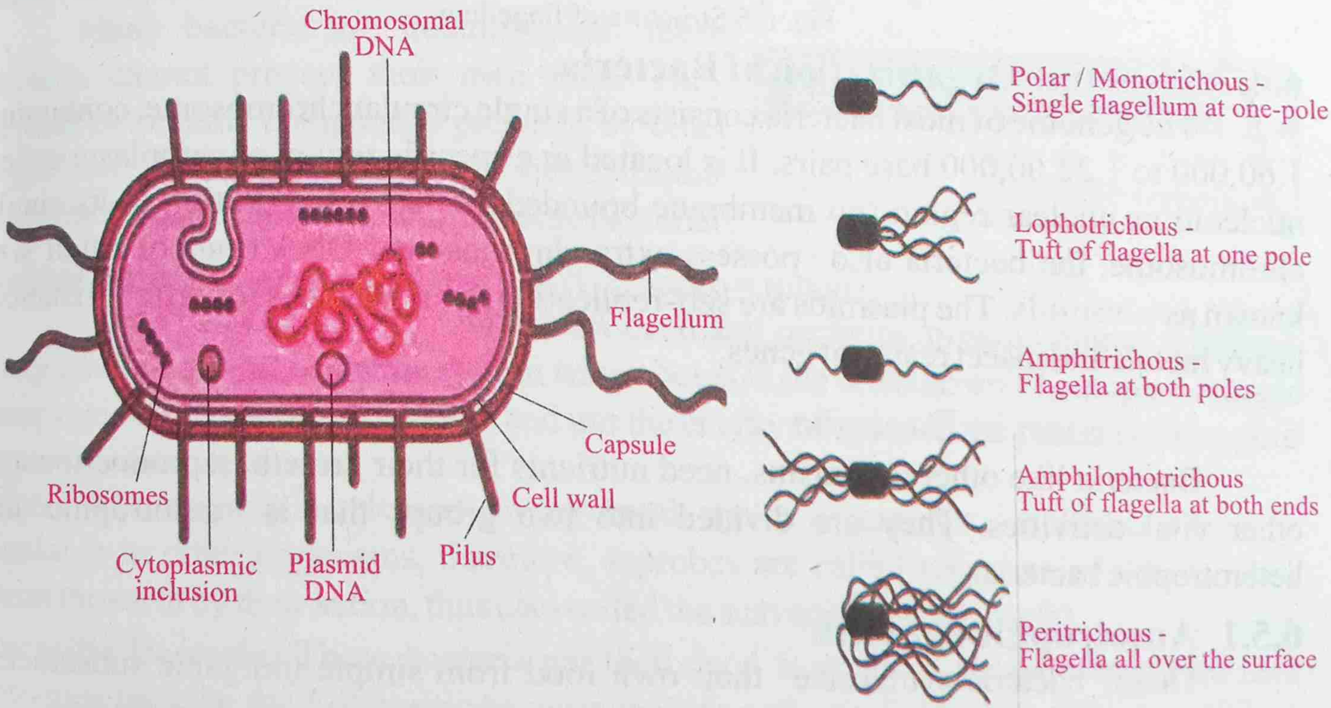

Fig. 6.5 Generalized structure of bacterium and types of flagellar arrangement

6.4.6 Structure of Flagella

A flagellum is made of three parts, i.e., basal body, a short curved hook and a helical filament, consists of several protein chains. Protein of flagella is flagellin.

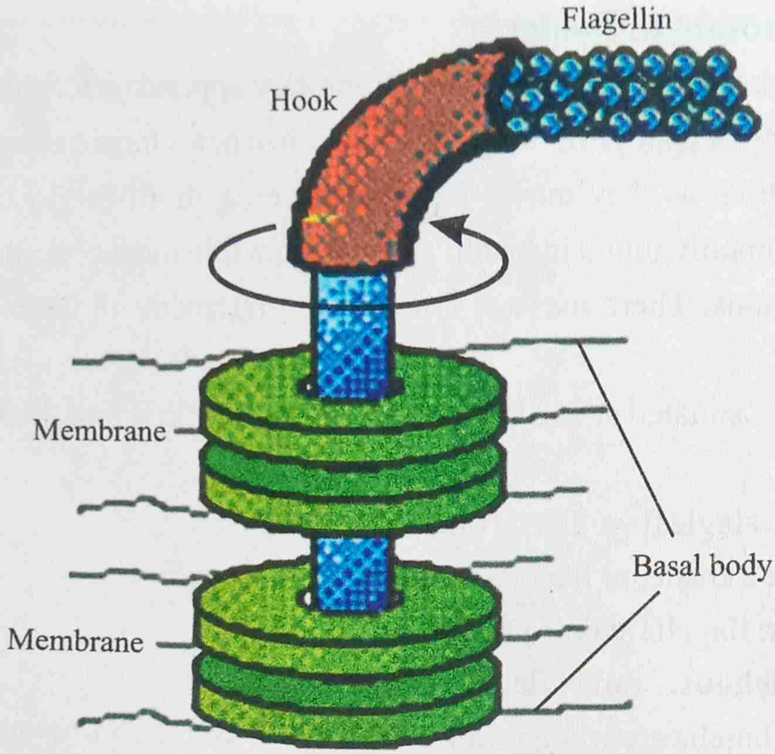

Fig. 6.6 Structure of flagellum

6.4.7 Genomic Organization of Bacteria

The genome of most bacteria consists of a single circular chromosome, containing 1,60,000 to 1,22,00,000 base pairs. It is located in a specific region of cytoplasm called nucleoid or nuclear region (no membrane bounded nucleus). In addition to its single chromosome, the bacteria also possess extra chromosomal DNA rings of small size known as **plasmids**. The plasmids are self-replicating, contain genes for drug resistance, heavy metals and insect resistant genes.

6.5 Nutrition in Bacteria

Bacteria like other organisms, need nutrients for their growth, reproduction and other vital activities. They are divided into two groups that is autotrophic and heterotrophic bacteria.

6.5.1 Autotrophic bacteria

These bacteria synthesize their own food from simple inorganic substances. They obtain all the carbon from inorganic carbon compounds such as carbon dioxide. The autotrophic bacteria are further divided into two groups namely photoautotrophic and chemoautotrophic.

Photoautotrophic or Photosynthetic Bacteria:

These bacteria possess chlorophyll, located either in the membrane of their mesosomes or freely dispersed in cytoplasm. Bacteria have unique type of chlorophyll

that is chlorophyll *e* and *f* are known as **bacteriochlorophylls**. Photoautotrophic bacteria use the energy of sun light, H_2S as "H" source (instead of H_2O) and liberate "S" instead of O_2 to make carbohydrate (organic food) from CO_2.

$$2H_2S + CO_2 \xrightarrow[\text{Chlorophyll}]{\text{Sunlight}} \underset{\text{Carbohydrate}}{(CH_2O)_n} + H_2O + 2S$$

Examples of photosynthetic bacteria are purple sulphur bacteria, green sulphur bacteria, purple non-sulphur bacteria.

Chemoautotrophic or Chemosynthetic Bacteria:

These bacteria do not have chlorophyll thus do not use sunlight as source of energy. They derive energy by oxidation of inorganic substances such as H_2S, NH_3, NO_2, NO_3 and iron compounds. The energy of above inorganic substances is used to synthesize carbohydrates.

$$2H_2S + O_2 \xrightarrow{\text{oxidized}} 2S + H_2O + \text{release energy}$$

The energy released is utilized to make carbohydrates.

$$2H_2S + CO_2 + \text{energy from oxidation} \longrightarrow (CH_2O)_n + H_2O + 2S$$

The example of chemosynthetic bacteria are denitrifying bacteria, sulphur bacteria.

Heterotrophic Bacteria:

Many bacteria are heterotrophic, these bacteria cannot prepare their own food. They depend on organic compounds prepared by other organisms. There are two types of heterotrophic bacteria that is saprotrophic and parasitic bacteria.

> **Do you know?**
> *Heterotrophs directly or indirectly depend on photosynthetic organisms.*

Saprotrophic Bacteria or Saprobs (Gk. Sapro = rotten)

These bacteria get their food from dead and decaying organic matter (Humus). They have a powerful enzyme system which helps in the breakdown of complex organic compounds into simple substances and use the energy released in the process. Examples: *Pseudomonas, Azobacter.*

(**Note:** The chemicals released during break down of organic substances become available to other organisms, therefore, saprobes are called recyclers of nature. They clean the earth by their action, thus also called the scavengers of the earth).

Parasitic Bacteria: These bacteria get their food from the host and depend on host enzymes to make food. Parasitic bacteria include pathogenic bacteria (disease causing) examples are *Mycobacterium, Streptococcus pneumoniae.*

Respiration in Bacteria:

Respiration in bacteria may be aerobic and anaerobic.

Aerobic bacteria need oxygen to breakdown food, e.g., *Pseudomonas.*

Anaerobic bacteria breakdown food without oxygen, e.g., *Spirochetes.*

Facultative bacteria grow either in the presence or absence of oxygen, e.g., *E.coli.*

Microaerophilic bacteria need a low concentration of oxygen for their growth, e.g., *Campylobacter.*

6.6 Growth and Reproduction in Bacteria

Growth in bacteria means the increase in the total population rather than increase in the size of organism. Their growth is very fast and depend on suitable temperature, availability of nutrients, pH and ionic concentration; If conditions are favorable then most bacteria divide after every 20 minutes, e.g., *E.coli.* The interval between two successive divisions is known as **generation time**. It is different in different species.

6.6.1 The Growth Phases of Bacteria

There are following four phases of growth in bacteria.

Lag phase (no growth): Bacteria prepare themselves for coming division i.e., adapting to its new environment and growth has not yet achieved its maximum rate.

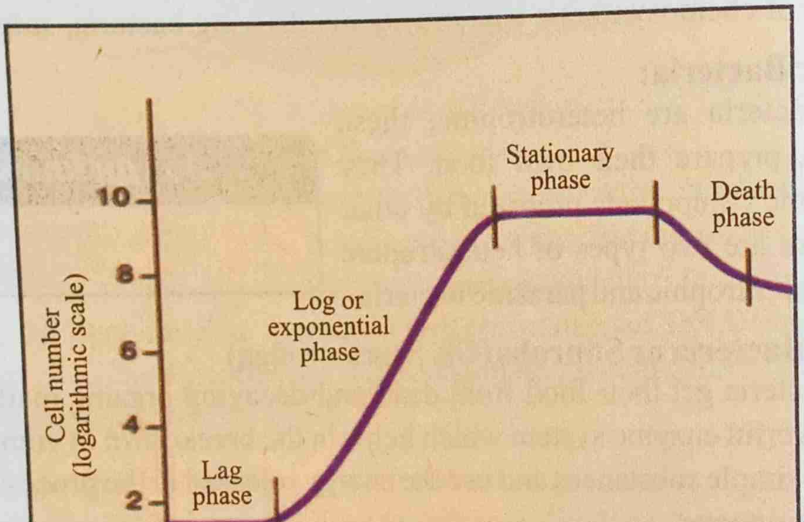

Fig. 6.7 Growth Curve of Bacterial Population

Log phase (rapid growth period): Fast growth occurs at this phase. In human the disease symptoms develop during the log phase because the bacterial production attains such a high level which damage the tissues.

Stationary phase (equal birth and death rate): After log phase, the growth slows down because of shortage of nutrients. Thus rate of reproduction and death of bacteria becomes equal.

Death phase (decline phase): In this phase death rate increases and reproduction rate decreases. It is due to exhaustion of nutrients and accumulation of toxic wastes.

6.6.2 Reproduction in Bacteria

Bacteria reproduce both asexually and sexually.

Asexual Reproduction (Binary fission): All bacteria reproduce asexually by means of **binary fission.** There is a single chromosome, having a circular DNA molecule. First DNA is replicated and attached to the plasma membrane. After duplication the two chromosomes move towards their respective sides. The plasma membrane pushes inward at the center of the cell. The cell wall grows inwards to separate both daughter cells from each other thus two daughter bacteria are formed. In most bacteria, it takes 20 minutes, if conditions are favourable.

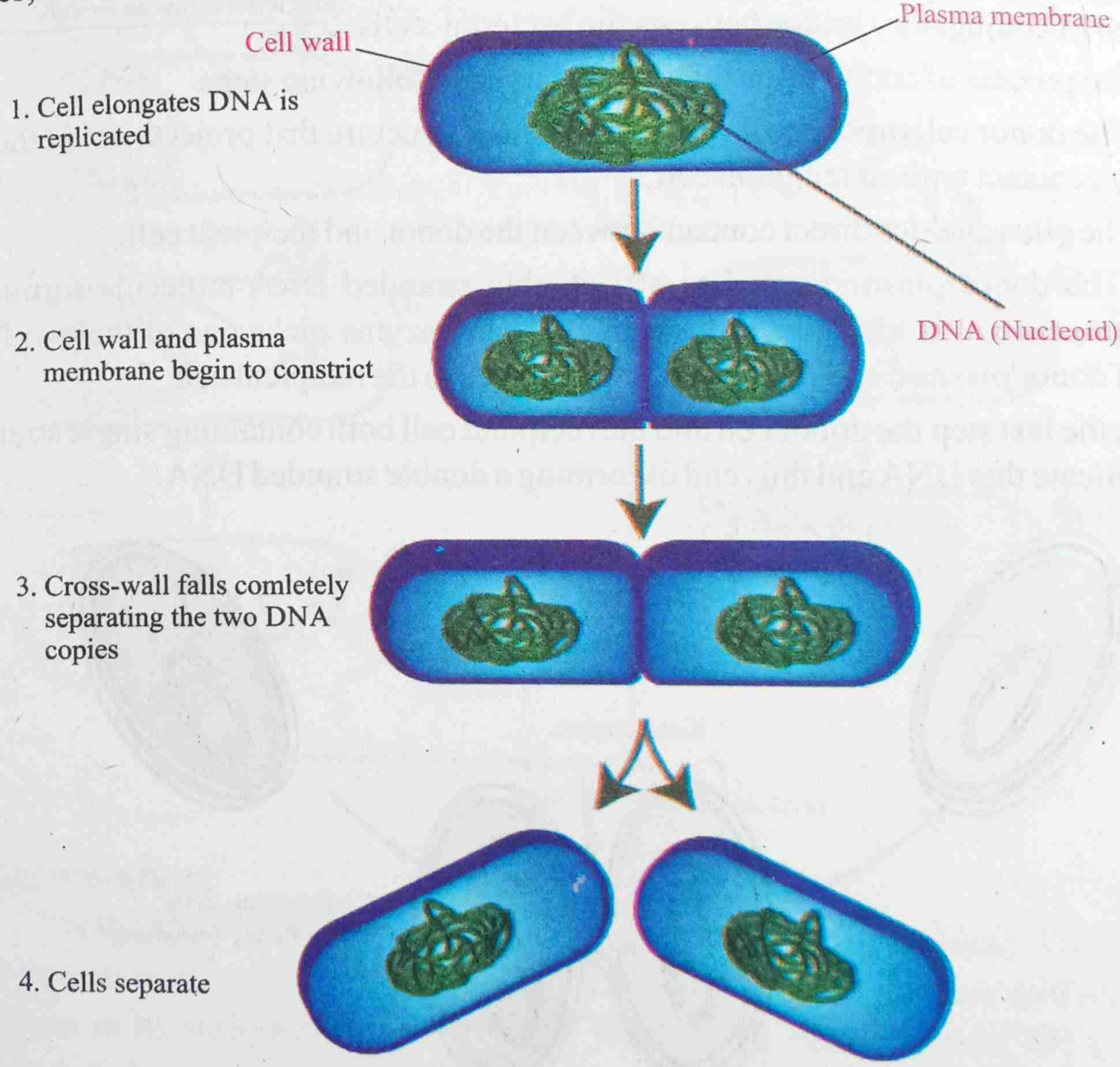

Fig. 6.8 Binary Fission in Bacteria

Sexual Reproduction in Bacteria:

Bacteria lack traditional sexual reproduction (gametogenesis). However, bacteria exhibit genetic recombination that is cells do not fuse, only piece of DNA or plasmid of donor cell is inserted in the recipient cell. This process occurs by conjugation,

transduction and transformation.

Conjugation:

It is the process by which one bacterium transfers genetic material to another bacterium through a tube formed by pili called conjugating tube or bridge. The bacterium that gives the DNA is called **donor** and the bacterium that receives DNA is called the **recipient.** This process was, first studied experimentally by Lederberg and Tatum in 1946 in *E. coli*. Later studies made with the help of electron microscope confirmed the close contact and the formation of conjugatory bridge between the bacterial cells.

Tit bits

A cell possessing the F plasmid (F+, Male) can form a conjugation bridge to cell lacking the F plasmid (F-, Female) through which genetic material may pass from one cell to another. Now F- cell has its own fertility plasmid and it becomes an F+ cell.

The process of conjugation may be explained in following steps.

Step 1: The donor cell produces the pilus, which is a structure that projects out of the cell and begins contact with an recipient cell.

Step 2: The pilus enables direct contact between the donor and recipient cell.

Step 3: The donor plasmid consists of a double stranded DNA molecule forming a circular structure, it is attached at the both ends, an enzyme picks one of the two DNA strands of donor plasmid and this strand is transferred to the recipient cell.

Step 4: In the last step the donor cell and the recipient cell both containing single stranded DNA, replicate this DNA and thus end of forming a double stranded DNA.

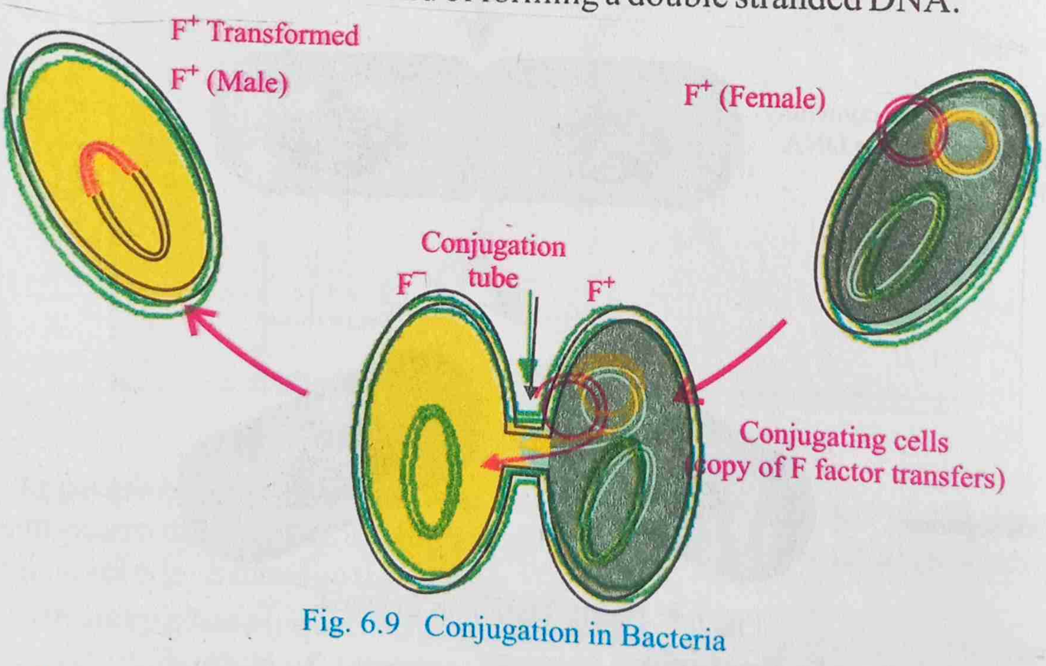

Fig. 6.9 Conjugation in Bacteria

Transduction:

It is a type of sexual reproduction, in which piece of DNA can be transferred from one bacterium (donor) to another bacterium (recipient) by a third organism, the

bacteriophage. The process of transduction was discovered by Norton Zinder and Joshua Lederberg in 1952 while studying the genetic recombination in *Salmonella.*

In general transduction, any of the genes from the host cell may be involved in the process, in special transduction, however, only a few specific genes are transduced.

> **Tit bits**
>
> *There are typically 40 million bacterial cells in a gram of soil and 1 million in 9 ml of fresh water and 5×10^{30} bacteria on earth.*

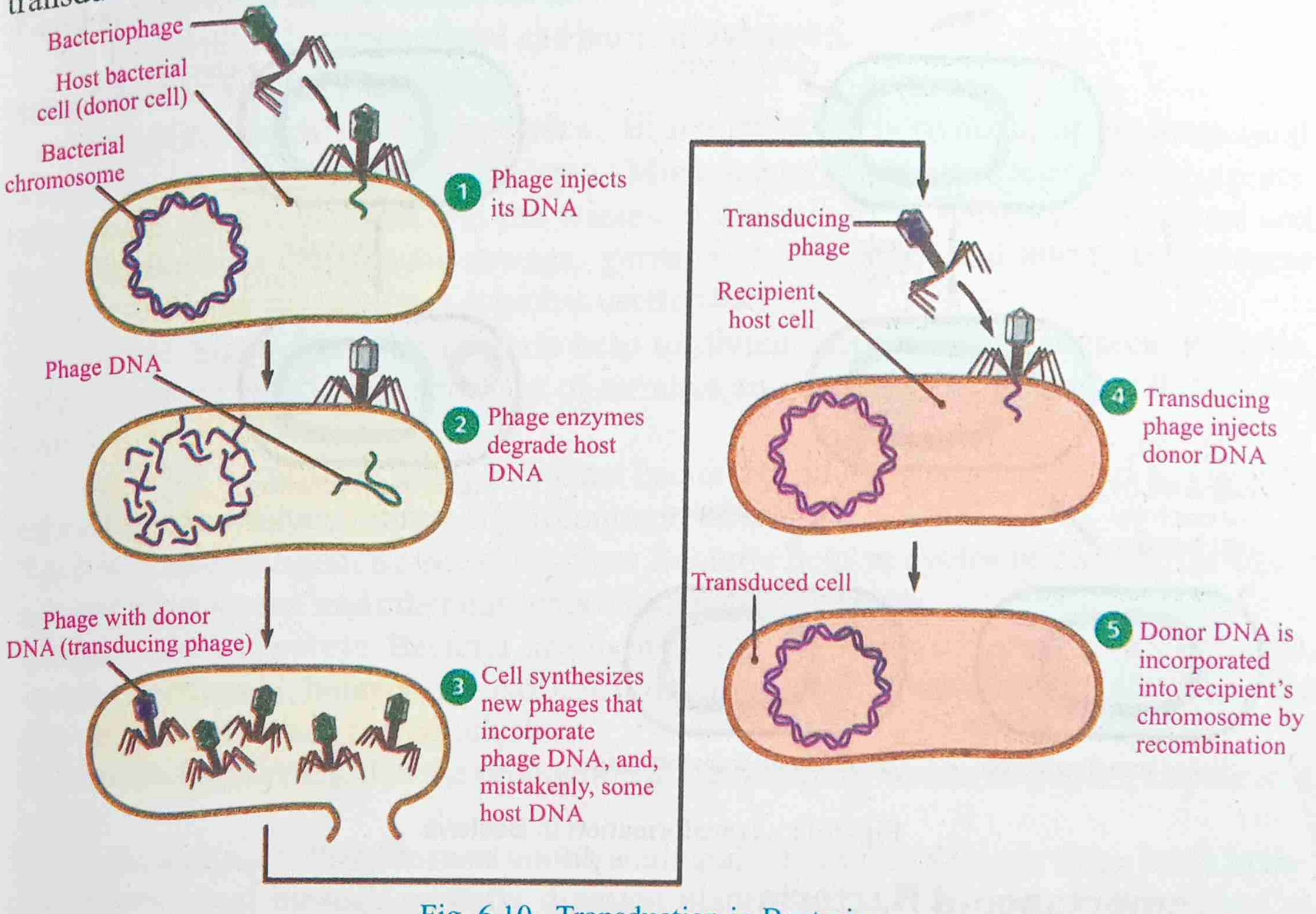

Fig. 6.10 Transduction in Bacteria

Transformation:

It is the absorption of DNA from a solution into a bacterium (cell). These cells are called transformed cells. The fragments of DNA are released after the death of a donor bacterium to its surrounding environment. Now if one of the released DNA fragment contacts a species of bacterium that is capable of transformation. The DNA fragment may be bound to recipient and is taken inside.

Griffith (1928) proved the process of transformation while experimenting on *Pneumococcus,* the bacteria which causes pneumonia.

Receptivity for transmission is present for a brief period when the cell have

reached the end period of active growth. At this time they develop specific receptor site in the wall. Normally *E. coli* does not pickup foreign DNA but it can do so in the presence of calcium chloride.

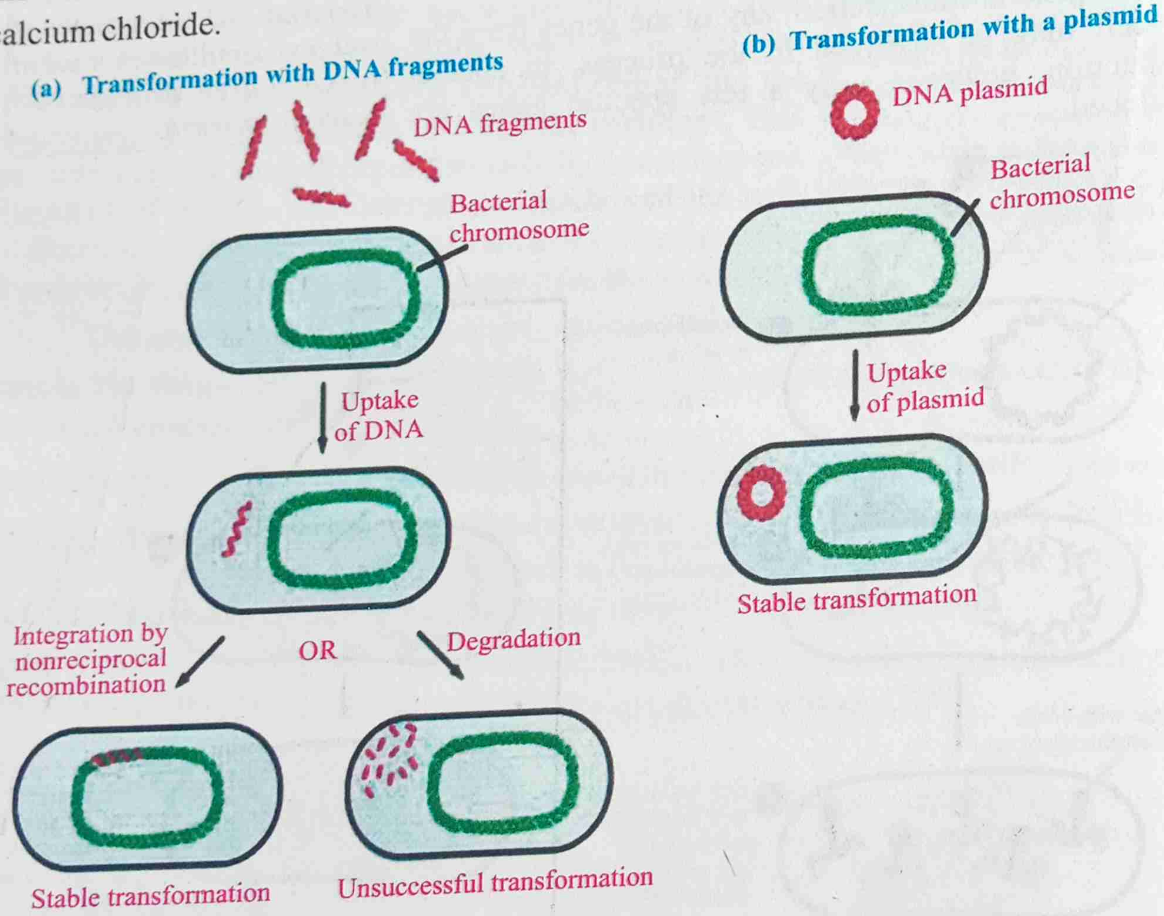

Fig. 6.11 Transformation in Bacteria

6.7 Importance of Bacteria

- Bacteria live everywhere because they have ability to survive in all conditions.
- They can adjust themselves according to environment, thus exhibit great ecological and economic importance, they are useful as **recyclers** of nature.
- Many bacteria involve in the steps of **nutrient cycles** e.g., carbon cycle are controlled by bacteria because of decomposition of remains of dead organisms. Denitrifying bacteria play role in denitrification .
- The genus *Rhizobium,* live in root nodules of legume plants converts nitrogen gas into nitrates.
- If bacteria were not present in universe, the CO_2 from the atmosphere would have diminished. Thus there would have been no photosynthesis and no possibility of life on earth.

6.7.1 Ecological Importance of Bacteria

The decomposition of dead organisms and wastes is carried out mostly by bacteria and fungi, which convert organic matter into humus. It contains nutrients and increases soil fertility for the growth of plants. Humus also retains water, thus increases water holding capacity of the soil. The **leguminous plants** have mutualistic association with the bacteria (Root nodules) which transform nitrogen into nitrates.

Economic Importance of Bacteria:

Bacteria are both beneficial and harmful to human.

Beneficial or Useful Bacteria:

Bioremediation and Decomposers: Bioremediation is removal of environmental pollutants by using living organisms. Most bacteria act as decomposing agents, decompose dead organisms and the wastes of animals to be reused by the plants and animals. Bacteria decompose sewage, garbage, dungs, stool and during this process produce methane gas or biogas, which is used as fuel.

Digestion: Some intestinal bacteria help to divide fats into small droplets in cattle, others produce cellulase, (in the gut of termites and cattle) which digest cellulose and starch.

Synthesis of Vitamins: Many intestinal bacteria produce vitamins, B and K. Bacteria are cultured to produce vitamin B_{12} on commercial scale.

Bacteria and Biogeochemical Cycles: Bacteria help in cycles of carbon, nitrogen, sulphur, phosphorus and other nutrients through the biosphere.

Bacteria in industry: Bacteria are used in the synthesis of vinegar (acetic acid), acetone, lactic acid, butanol (alcohol), several vitamins and flavoring tobacco. They are also used in leather and coffee industries.

In food industry: Used in the production of dairy products such as yogurt, cheese and butter.

Bacteria as Food: Provide most amino acids and vitamins to animals when enter in the alimentary canal through partially digested plant materials. A **single cell protein** is obtained from the large scale growth of microorganisms such as bacteria.

Antibiotics: Several antibiotics are obtained from actinomycetes group, e.g., streptomycin, teramycin and aureomycin.

Genetics: Bacteria are used for studying the principles of genetics, such as *E. coli*.

Harmful Bacteria:

Bacterial Diseases in Plants: Parasitic bacteria infect plants and cause various diseases, e.g., fire blight in apple and pear, ring disease in potato and crown galls.

Bacterial Diseases in Man: Many human diseases are caused by bacteria; like tuberculosis, diphtheria, tetanus, cholera, leprosy, typhoid fever, meningitis, sore throat, whooping cough etc.

Bacterial Diseases in Animals: Chicken cholera, anthrax, TB etc.

using ...

6.8 The Bacterial flora of human

Flora: It is the plant life occurring in a particular region at a particular time. The **normal flora** is the population of micro-organisms routinely found growing on the body of healthy persons.

Resident flora: live for extended period in the body of infected person.

Transient flora: temporarily live.

Many microorganisms make up normal flora, which occur in large number. In fact, there are more bacteria in just one person's mouth than there are people in the world.

Table 6.3 Some Members of Normal Bacterial Flora

Members of Normal Flora	Anatomic Location
Clostridium species	Colon
Escherichia coli, Lactobacillus	Colon, vagina, outer urethra
Lactobacillus species	Mouth, colon, vagina, uterus
Staphylococcus aureus, Corynebacterium	Nose, skin, respiratory tract, tongue
Enterococcus faecalis, E. coli	Colon, (Predominantly intestinal bacteria)
Viridans streptococci	Mouth, nasopharynx.

Benefits of normal bacterial flora to Human

(1) Normal flora protects us against potentially harmful microorganisms.

(2) The normal flora also plays an important role in the development of immune responses.

(3) Produces some nutritional substances. Many intestinal bacteria produce vitamin B and K.

6.9 Control of Harmful Bacteria

Microorganisms can be controlled by physical or chemical methods.

Physical methods

Sterilization: This method is useful to kill all life forms, in which physical agents like steam, dry heat, gas filtration and radiations are used. It is the destruction of all life forms. It is used to sterilize surgical instruments. It is also used to preserve milk and meat on large scale.

High temperature: This method is used in microbiological laboratories in which both dry and moist heat are effective. Moist heat helps in coagulation of proteins and kills the microbes. Dry heat causes oxidation of chemical constituents of microbes and kill them.

Radiation: Microbes are killed by electromagnetic radiation below 300 nm. Gamma rays are generally used for this purpose.

Membrane filter: Heat sensitive materials like antibiotics, sera, hormones, growth media, enzymes, vitamins can be sterilized by using membrane filters. In hospitals some operation theaters and burn wards receive filtered air to lower the number of air borne microbes.

Pasteurization: This process was developed by Louis Pasteur to kill non-spore forming bacteria, e.g., milk is pasteurized by heating at $71^{\circ}C$ for 15 seconds and at $62^{\circ}C$ for 32 minutes to destroy Tuberculosis and Typhoid bacteria in milk. Pasteurization does not change the taste of milk.

Low temperature: Low temperature **(10-15°C)** can preserve food for several days, such as milk, egg, meat, cheese and vegetables.

Freezing: Meat and some vegetables can be prevented from microbial destruction by freezing at below **0°C (-10 to -18°C)** for several weeks to several months.

Drying: In this method water is removed from food like meat, milk, vegetables etc, thus bacteria can not grow because their enzymes need water for action.

Preservatives: Many preservatives stop the growth of microbes, e.g., **Acid** lowers the pH, salts and sugar decrease water in food, the reduced water checks the growth of bacteria.

Certain chemicals: Like potassium metabisulphate stops bacterial growth when added in pickles, candies, jams, bread and biscuits.

Chemical methods to control bacteria:

Following chemical methods are used to control microbes.

Antiseptics: There are certain chemical substances (such as iodine, Dettol) that stop the growth of microbes called antiseptics.

Disinfectants: Certain chemicals like halogens and phenols, H_2O_2, potassium permanganate, alcohol and formaldehyde etc., are oxidizing and reducing agents that inhibit the growth of vegetative cells and are used on non-living materials.

Chemotherapeutic agents: Certain chemicals and antibiotics destroy and stop the growth of microbes in cells, e.g., penicillin, tetracycline etc.

6.10 Cyanobacteria

Why cyanobacteria are considered as the most prominent of the photosynthetic bacteria?

Cyanobacteria played major role in the evolution of life. They were the first oxygen producing organisms. Their photosynthetic activity gradually oxygenated the

atmosphere and the oceans about two billion years ago. The level of oxygen increased by cyanobacteria, i.e. to about 21%. The amount of **ozone** also increased in the upper layers of the atmosphere by cyanobacteria. Ozone acted as a screen to protect the nucleic acids and proteins from destruction by ultra violet radiations from the sun.

It encouraged other autotrophs to appear and survive on earth. Many of cyanobacteria (about one third) are involved in the **fixation of atmospheric nitrogen** to produce nitrates e.g., Anabaena and Nostoc are purposely cultivated to increase the soil fertility, because of nitrogen fixation ability of these organisms.

Characteristics of Cyanobacteria

Habitat: These are found in damp places, salt water, fresh water, in moist soil, hot springs (with temperature up to 85°C).

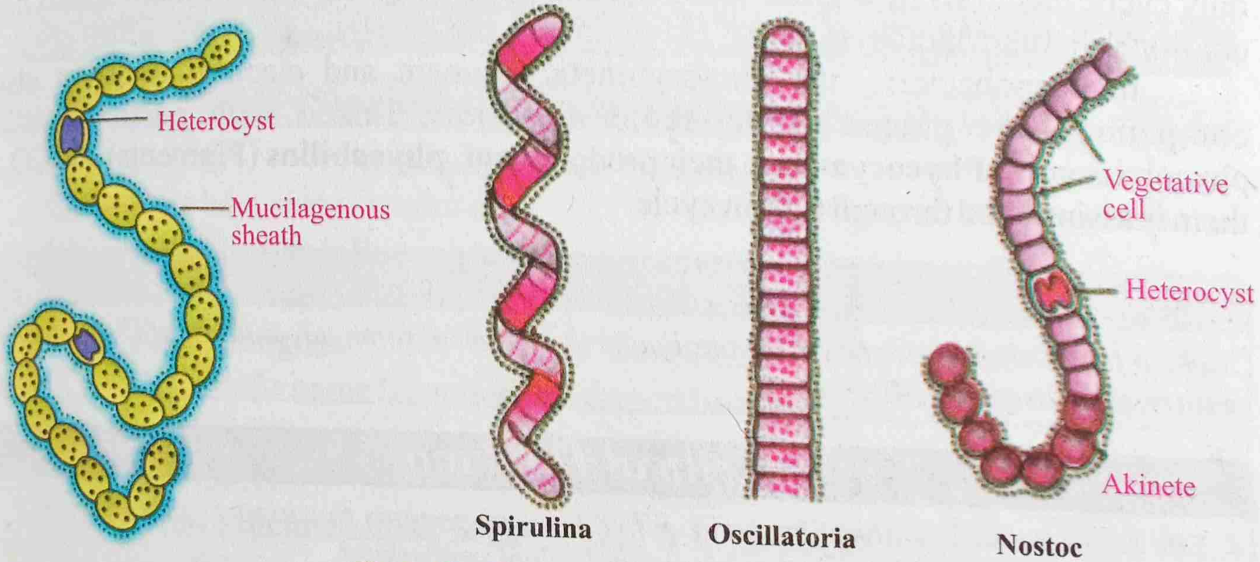

Fig.6.17 Examples of Cyanobacteria

Mode of life: May be epiphytic and symbiotic.

Form of life: May be unicellular and solitary, exist as colonies of many shapes, or form filaments consisting chains of cells (trichomes) surrounded by mucilaginous sheath.

> **Do you know?**
> *Bacterial cell membrane lacks cholesterol.*

Cell wall is Gram negative type (contains lipopolysaccharides, lipoproteins, peptidoglycan).

Photosynthetic System closely resembles to eukaryotes because cyanobacteria have chlorophyll *a* and photosystem II, use water as an electron donor and generate oxygen during photosynthesis. They have phycobilins as accessory pigments. Phycocyanin is their predominant pigment. The photosynthesis takes place in the extensive system of membrane, which is placed in the periphery of the cytoplasm.

6.10.1 Pigment Composition in Cyanobacteria

Cyanobacteria possess two accessory pigments, i.e., phycocyanin (blue pigment) and phycoerythrin (red pigment). In some species the mixture of chlorophyll and blue pigment, produces the blue green color, thus sometime known as blue green algae. But the other species contain red pigments, appear red, purple brown or even black.

6.10.2 Difference between the photosynthetic mechanisms in cyanobacteria and photosynthetic bacteria.

The photosynthetic bacteria release sulphur whereas cyanobacteria release oxygen during photosynthesis. The source of hydrogen in bacteria is hydrogen sulphide whereas cyanobacteria like plants obtain hydrogen from water.

The photosynthetic bacteria have photosystem I but lack photosystem II, thus only cyclic electrons flow is the sole means of generating ATP while cyanobacteria have chlorophyll *a* and photosystem II.

In cyanobacteria, the photosynthetic pigment and electron transport chain components are placed in thylakoid membrane linked with particles called phycobilisomes. **Phycocyanin** is their predominant **phycobilins** (Pigments) and CO_2 in them is assimilated through Calvin cycle.

Activity

Make a list of characteristics of Cyanobacteria and write some advantages of Cyanobacteria with respect to soil fertility.

Critical Thinking

1. *Life is not possible without bacteria. Why? Give arguments to support this statement.*
2. *Why bacteria are widely used in biotechnological processes?*

EXERCISE

Section I: Objective Questions

Multiple Choice Questions

A. **Choose the best correct answer.**

1. Which of the following term describes most of the bacteria?
   (a) Anaerobic (c) Many-celled
   (b) Pathogens (d) Beneficial
2. What is the name for spherical-shaped bacteria?
   (a) Bacilli (c) Spirilla
   (b) Cocci (d) Colonies
3. What structure allows bacteria to stick to surfaces?
   (a) Pili (c) Chromosome
   (b) Flagella (d) Cell wall
4. Which of these organisms are recyclers in the environment?
   (a) Producers (c) Saprophytes
   (b) Carnivores (d) Pathogens
5. Which of the following is caused by a pathogenic bacterium?
   (a) AIDS (c) Nitrogen fixation
   (b) Cheese (d) Tetanus
6. Which of the following cannot be found in a bacterial cell?
   (a) Ribosomes (c) Chromosome
   (b) Nucleus (d) Cytoplasm
7. Which organism of the following can grow as blooms in ponds?
   (a) Archaebacteria (c) Cocci
   (b) Cyanobacteria (d) Viruses

8. A bacterium with a tuft of flagella at one side of the body.
(a) Lophotrichous
(b) Amphiptrichous
(c) Peritrichous
(d) Non of the above

9. Asexual reproduction in bacteria is called.
(a) Budding
(b) Binary fission
(c) Multiple fission
(d) Both A and B

Fill in the blanks.

1. Pili are made of protein called ________.
2. Flagella are made of a protein called ________.
3. The cell wall of bacteria is made of ________.
4. ________ are straight or rod shape bacteria.
5. Bacterium having single flagellum is called as ________.
6. The bacterium that gives the DNA during conjugation is called ________
7. Typhoid is caused by ________.
8. Tuberculosis is caused by ________.